

ORIGINAL

PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION  
International Bureau

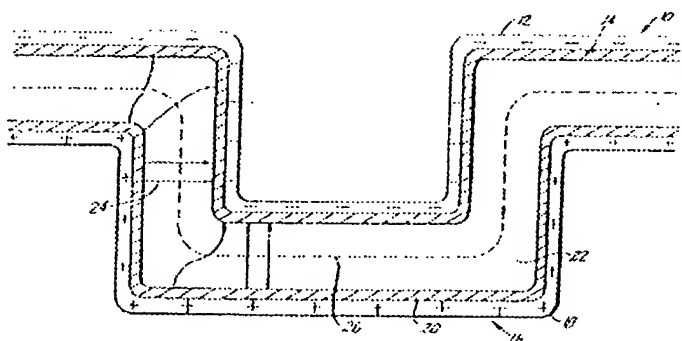
W4

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification <sup>5</sup> :  G21B 1/00	A1	(11) International Publication Number: WO 91/08573
		(43) International Publication Date: 13 June 1991 (13.06.91)
(21) International Application Number: PCT/US90/07073	(81) Designated States: AT, AT (European patent), AU, BE (European patent), BR, CA, CH, CH (European patent), DE, DE (European patent), DK, DK (European patent), ES, ES (European patent), FI, FR (European patent), GB, GB (European patent), GR, GR (European patent), HU, IT (European patent), JP, KR, LU, LU (European patent), NL, NL (European patent), NO, SE, SE (European patent), SU.	
(22) International Filing Date: 4 December 1990 (04.12.90)		
(30) Priority data: 446,615                      6 December 1989 (06.12.89)    US		
(71)(72) Applicants and Inventors: BUSH, Robert, T. [US/US]; 1553 Shamrock Avenue, Upland, CA 91768 (US). EAGLETON, Robert, D. [US/US]; 1572 North Mountain Avenue, Claremont, CA 91711 (US).		
(74) Agents: FISCHER, Felix, L. et al.; Christie, Parker & Hale, 350 West Colorado Blvd., Ste. 500, Pasadena, CA 91109-7068 (US).	<p><b>Published</b>  <i>With international search report.</i>  <i>Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i></p>	

COPY

(54) Title: METHOD AND APPARATUS FOR ENERGY PRODUCTION USING COLD NUCLEAR FUSION WITH A LITHIUM DEUTEROXIDE ELECTROLYTE



## (57) Abstract

The present invention enables nuclear fusion of deuterons and lithons. A crystalline lattice (14) having octahedral interstitial sites aligned with an electrical field (24) is exposed on a first surface to a electrolytic solution of heavy water and lithium deuterioxide contained in a channel (22). Deuterium and lithium atoms from the electrolyte are absorbed into the crystalline structure where their electrons are stripped to produce deuterons and lithons, the latter retaining two electrons. Under the influence of the electric field, deuterons tunnel through the lattice and collect in interstitial sites to provide a palladium-deuteride lattice (the  $\beta$  phase of palladium). A barrier, which may comprise an electrode (12) on which the crystalline lattice is deposited, is introduced which terminates the lattice perpendicular to the electric field to preclude further tunneling or diffusion of the deuterons from the interstitial sites adjacent the barrier. Heating of the electrolytic solution enhances the overlap of the energies of the diffusing particles with transmission resonance energy levels specific to the metal deuteride lattice and the particles diffusing through it. This promotes the diffusion of deuterons and lithons from the electrolyte into the lattice increasing the probability of fusion reactions between diffusing particles and the deuterons already in the lattice interstitial sites. Heat generated from the fusion reactions is extracted from the crystalline lattice and employed for power generation.

**FOR THE PURPOSES OF INFORMATION ONLY**

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AT	Austria	FI	Finland	ML	Mali
AU	Australia	FR	France	MN	Mongolia
BB	Barbados	GA	Gabon	MR	Mauritania
BE	Belgium	GB	United Kingdom	MW	Malawi
BF	Burkina Faso	GN	Guinea	NL	Netherlands
BG	Bulgaria	GR	Greece	NO	Norway
BJ	Benin	HU	Hungary	PL	Poland
BR	Brazil	IT	Italy	RO	Romania
CA	Canada	JP	Japan	SD	Sudan
CF	Central African Republic	KP	Democratic People's Republic of Korea	SE	Sweden
CG	Congo	KR	Republic of Korea	SN	Senegal
CH	Switzerland	LI	Liechtenstein	SU	Soviet Union
CI	Côte d'Ivoire	LK	Sri Lanka	TD	Chad
CM	Cameroon	LU	Luxembourg	TG	Togo
DE	Germany	MC	Monaco	US	United States of America
DK	Denmark	MG	Madagascar		
ES	Spain				

1

5

-1-

10

METHOD AND APPARATUS FOR ENERGY PRODUCTION  
USING COLD NUCLEAR FUSION  
WITH A LITHIUM DEUTEROXIDE ELECTROLYTE

Cross-Reference to Related Applications

15

This is a continuation-in-part of prior U.S. Patent Application Serial Number 07/352,853, filed on May 15, 1989, in which a method and apparatus employing a crystalline palladium lattice for the production of energy using cold nuclear fusion is described in detail and incorporated herein by reference.

20

Field of the Invention

25

30

35

The present invention relates generally to production of power through the use of a steam turbine system receiving heat energy from a nuclear fusion reactor. More particularly, the invention provides a crystalline/palladium lattice reactor aligned in an electric field to receive deuterons into interstitial lattice sites from a deuterium source. The crystalline lattice is blocked perpendicular to the electric field in the lattice at a given depth preventing migration of deuterons out of the lattice. The crystalline lattice is immersed in a heavy water electrolyte solution containing lithium deuterioxide (LiOD). A heater maintains the electrolyte solution at an elevated temperature to increase the number of transmission resonance levels available for deuteron and lithium diffusion in the

1 lattice. Use of a high purity of  $\text{Li}^6$  isotopes in the  
lithium deuterioxide enhances the reactor by reducing the  
probability of tritium production. Heat energy generated  
in the fusion is conductively transferred to a liquid  
5 coolant system and steam driven turbines for power  
generation.

#### Background of the Invention

Basic concepts for the generation of energy through  
10 nuclear fusion have centered on the so-called "hot" fusion  
approach. In "hot" fusion, deuterium atoms are forced  
together under great pressure and temperature sufficient  
to provide energy to overcome the Coulomb repulsion force  
and drive together the nuclei of the deuterium atoms to  
15 fuse. The result is nuclear fusion to produce an  $\text{He}^3$   
nucleus plus a neutron or a tritium nucleus plus a proton.  
Temperatures of  $10^8$  degrees K are required to provide  
sufficient energy to overcome the Coulomb barrier of the  
deuterons.

20 In a palladium lattice loaded with deuterons, a  $\beta$   
phase of palladium is produced which may significantly  
increase the probability for nuclear reactions between  
deuterons diffusing through the lattice and the deuterons  
fixed in the lattice producing the  $\beta$  phase. It has been  
25 suggested by L. Turner in his letter to the editor  
published in Physics Today, 1989, pp. 140-141, that cold  
fusion may involve transmission resonances for deuterons  
diffusing through a periodic array of wells formed by the  
Coulomb barriers of the deuterons sitting at the  
30 interstitial sites. The resonance condition of

$$\int \kappa(x) dx = (n + 1/2) \pi$$

will provide a transmission coefficient of unity if  
35 satisfied by the wave number of the particle crossing the  
potential well between two neighboring barriers where  $\kappa(x)$

1 is the wave number of the diffusing particle. A  
transmission resonance condition may be hypothesized as

$$(2n + 1) \lambda/4 = L$$

5

where  $n = 0, 1, 2, \dots$ .  $\lambda$  is the de Broglie wavelength  
of the diffusing deuteron and  $L$  is the width of the well  
in the array. Electron screening of the deuterons by the  
palladium lattice will make the wells shallower than  
10 normal. Transmission will, therefore, occur for a  
diffusing deuteron whenever an odd number of quarter  
wavelengths of the deBroglie waves fit into the well  
width. Bohm has noted in Quantum Theory, Prentice-Hall,  
Inc., Inglewood Cliffs, New Jersey, 1951, p. 287, that "it  
15 is especially interesting that although a single high and  
thick barrier has a very small transmissivity, two such  
barriers in a row can be completely transparent for  
certain wavelengths. This barrier can be understood only  
in terms of the wave-like aspects of matter. The high  
20 transmissivity arises because, for certain wavelengths,  
the reflected waves from inside interfere destructively  
with those from outside so that only a transmitted wave  
remains."

As also shown by Bohm, the resonance condition also  
25 expresses the condition for existence of metastable or  
virtual states associated with wells having barriers.  
These states are unbounded and have a relative long  
lifetime due to the fact that deBroglie waves associated  
with the deuterons reflect back and forth in the well many  
30 times before the barrier is penetrated. The energies of  
these states may be found by combining the transmission  
resonance condition equation with the following well known  
relations:

35

$$E = p^2/2m \text{ and } \lambda = h/p,$$

1        where  $p$  is the momentum of the diffusing deuteron and  $m$   
is its mass. Combining these equations yields the  
metastable state energies:

$$E_n = (2n + 1)^2 \hbar^2 / 32m L^2.$$

Since these energies are based on the resonance condition to achieve transmission, these are also the energies for the transmission resonances.

10            If occupation of a metastable state is proportional  
to the Boltzmann factor:

$$\exp(-E_n/kT),$$

15 where  $k$  is the Boltzmann's constant and  $T$  is the temperature in Kelvin, the energies may be expressed in terms of temperatures  $T_n$ .

$$E_p = kT_p.$$

20

The Boltzmann factor may then be rewritten:

$$\exp(-T_n/T).$$

25     Substituting for the energy  $E_n$ , we find

$$T_n = (2n + 1)^2 h^2 / 32mkL^2.$$

30 This equation indicates the temperature relationship for resonance levels associated with the widths,  $L$ , of the wells in the array produced by the lattice as previously described.

An apparatus designed by Pons and Fleischmann has been reported in an article (see Fleischmann, M. and Pons, S., "Electro-chemically Induced Nuclear Fusion of Deuterium", submitted to Journal of Analytical Chemistry, March 20, 1989). The apparatus which was employed to

1 obtain the fusion reported in this paper was embodied in  
several forms. In a first embodiment, a palladium rod  
cathode and an encircling helical platinum anode were  
5 inserted in a heavy water ( $D_2O$ ) electrolytic solution  
connected with a potential providing a maximum current  
density of approximately  $512 \text{ mA/cm}^2$ . In an alternative  
configuration, a rectangular palladium sheet cathode was  
surrounded by a platinum sheet anode and operated in the  
heavy water electrolyte with current densities of  
10 approximately  $1.6 \text{ mA/cm}^2$ . With both configurations,  
evidence of nuclear fusion was reported. However, methods  
and apparatus to obtain consistent power generation with  
controllability of the fusion reaction and necessary  
reliability are unknown.

15 Nuclear effects have also been noted by H. O.  
Menlove, M. M. Fowler, E. Garcia, A. Mayer, M. C. Miller,  
R. R. Ryan, and S. E. Jones, as noted in a presentation  
to the Workshop on Cold Fusion Phenomena, May 23 through  
25, Santa Fe, New Mexico, entitled "The Measurement of  
20 Neutron Emissions from  $Ti + D_2$  Gas". Neutron emissions  
were noted from titanium shavings pressurized with  $D_2$  gas,  
cooled to liquid nitrogen temperature and warmed to 243  
K. Similar nuclear effects were seen in the Cassacia  
experiment reported by A. DeNinno, et al., in a  
25 presentation at the Workshop on Cold Fusion Phenomenon,  
May 23 through 25, Santa Fe, New Mexico, entitled "Neutron  
Emission from a Titanium Deuterium System", in which  
titanium blades were heated at 1,273 K in the presence of  
0.1 mbar of  $D_2$  gas, followed by lowering of the  
30 temperature to 773 K at 20 mbar  $D_2$ . Neutron emission was  
observed after reheating of the sample to 1,273 K. Again,  
however, methods and apparatus to obtain consistent power  
generation with controllability of the reaction present  
were not disclosed.

1     Summary of the Invention

      The present invention provides a method and apparatus  
for obtaining heat energy from cold fusion. A palladium  
crystalline lattice provides a containment structure for  
5     deuterons in the octagonal interstitial sites of the face  
centered cubic structure. Deuterons with sufficient  
energy will migrate through a uniform palladium lattice  
by tunneling through the covalent bond barriers of the  
lattice. By alignment of an electric field with the  
10     $\langle 1,1,0 \rangle$  direction of the palladium lattice diffusion of  
the deuterons through the lattice is enhanced. To  
preclude diffusing particles from transitioning completely  
through the lattice, a means for blocking further  
tunneling is provided.

15     In a presently preferred embodiment, the palladium  
lattice is structured as a plurality of single crystal  
rods with the  $\langle 1,1,0 \rangle$  direction of the individual lattice  
sites in the rods perpendicular to a first surface of the  
crystal. The first surface of the crystal is exposed to  
20    a source of deuterium atoms, such as a heavy water  
electrolyte solution, to provide a source of deuterons.  
The blocking member interfaces the crystalline lattice on  
another surface of the crystal perpendicular to the  
electric field to prevent tunneling of the deuterons  
25    completely through the crystal. Preferably the blocking  
member is a metallic structural member. The combination  
of the palladium crystal and the metallic member may  
operate as a cathode in an electrolytic cell.

      An electrolytic solution containing lithium  
30    deuterioxide ( $\text{LiOD}$ ) to provide lithium ions (lithons) and  
deuterium ions (deuterons) is employed in the cell.  
Deuterons diffusing into the palladium lattice create a  
 $\beta$  phase in the palladium which allows enhanced  
transmission of lithons and deuterons into the palladium  
35    deuteride lattice. The lithons and deuterons react in the  
lattice in a cold fusion process producing heat energy.



1           By employing high purity  $\text{Li}^6$  isotopes in the lithium  
deuterioxide electrolyte, production of tritium is avoided  
thereby providing a "clean" reactor.

5           Configuration of the cathode as a structural dividing  
member allows containment of the electrolytic solution on  
the crystal surface of the cathode with circulation of a  
coolant fluid on the opposite side of the cathode to  
transport away heat generated by the fusion process in the  
10          lattice. A complementary anode structure of appropriate  
materials provides a second wall for the electrolyte  
container. Sealing between the edges of the electrodes  
with appropriate nonconductive material, such as quartz,  
completes the electrolyte container.

15          A heater is provided for the electrolytic solution  
to elevate the temperature for enhancement of transmission  
of the lithons and deuterons into the lattice by making  
more transmission levels in the palladium deuteride  
lattice available. Initiation of the fusion reaction is  
assisted by elevating the temperature of the electrolyte  
20          after loading of the palladium lattice with deuterons to  
achieve a  $\beta$  phase.

25          The potential applied across the electrodes is  
defined incrementally in magnitude by the desired  
transmission wavelength of the lithons and deuterons. The  
rate of the fusion process can be controlled by current  
density within the electrolytic cell. A larger forward  
current will increase power by accelerating tunneling of  
the lithons and deuterons in the lattice, while a reverse  
current will reduce tunneling in the lattice, shutting  
30          down the fusion reaction.

1     Brief Description of the Drawings

      The preferred embodiment of the invention is shown in the drawings.

5     FIG. 1 is a top cross-sectional view of the electrolytic cell;

      FIG. 2 is a pictorial representation of the palladium lattice.

      FIG. 3 is a pictorial sectional view of the elements of the electrolytic cell;

10    FIG. 4 is a pictorial schematic diagram of the reactor core;

      FIG. 5 is a schematic diagram of the reactor power plant;

15    FIG. 6 is a side cross-sectional view of one embodiment of the electrodes of the electrolytic cell employing a plurality of rods of palladium crystal;

      FIG. 7 is a representation of the resonant transmission temperature levels for a PdD lattice;

20    FIG. 8 is a graph of the dimensionless power factor for the palladium deuteride lattice; and,

      FIG. 9 is a graph of the temperature rate of change of the power factor.

25

30

35

1     Detailed Description

Referring to FIG. 1, two electrodes are shown. The first electrode 10 comprises a metallic structural member 12 with a palladium cladding 14. The structural member is configured in a corrugated pattern having multiple parallel channels for structural support and fluid cooling as will be described in greater detail subsequently. A second electrode 16 comprises a structural metallic member 18 with a cladding 20 of platinum or other nonreactive metal. The second electrode has a complementary shape to the first electrode and is mounted in spaced relation to the first electrode, creating a contained channel 22 between the two electrodes. This channel contains an electrolytic solution with purified heavy water ( $D_2O$ ) and lithium deuterioxide ( $LiOD$ ), or other metal deuterioxide which will be described in greater detail subsequently. A purity of 99.5%  $D_2O$  for the water in the electrolytic solution is preferred. Application of an electric potential across the two electrodes creates an electric field represented by field lines 24. The field will be perpendicular to the surface of each electrode. As is typical of electrolytic cells, deuterium gas will be evolved at the surface of the cathode, while oxygen gas will evolve at the surface of the anode. A spun quartz fiber screen 26, which bisects the channel between the electrodes, is employed to prevent mixing of the deuterium and oxygen gases as they rise to the top of the channel where they are vented into separate collection reservoirs, as will be subsequently described.

30     The palladium cladding on the cathode is arranged to provide a crystalline lattice of palladium having a significant plurality of the individual cells of the lattice each oriented with a  $\langle 1,1,0 \rangle$  direction parallel to the electric field at the electrode surface as well as the interior of the lattice. This condition is achieved by methods to be described in greater detail subsequently. As shown in FIG. 2 for a face centered cubic lattice 210,

1 the individual atoms 212 are joined by covalent bonds 214.  
The direction of view in FIG. 2 is along a  $\langle 1,1,0 \rangle$   
direction of the lattice. An electric field perpendicular  
to the electrode surface as shown in FIG. 1 is therefore  
5 perpendicular to the interstitial sites in each lattice  
cell through the associated covalent bonds. The  
arrangement of atoms in the lattice provides an octahedral  
interstitial site cornered by the atoms and bounded on  
each side by covalent bonds. Deuterium atoms adsorbed on  
10 the surface of the crystal lattice are drawn into the  
interior of the lattice by the electric field. As the  
deuterium atoms enter the electrode's interior they are  
stripped of their electrons. These electrons move into  
the Palladium conduction band and become delocalized from  
15 the deuterium nucleus, or deuteron. The deuteron is then  
acted on by the electric field and drawn through the  
lattice until a physical barrier is encountered which  
cannot be tunneled through or diffused around by the  
deuteron.

20 The stripping of the electron from the deuterium atom  
in effect transforms a fermion (the deuterium atom) into  
a boson (the deuteron).

The potential between the electrodes is established  
to provide an electric field for loading of the lattice  
25 having a magnitude to excite the deuteron wavelength for  
transitioning through the covalent bonds of the  
crystalline lattice. For this effect the deuteron  
wavelength is described by the equation:  $(\lambda) = 4L/n$ , where  
L is the distance across the octahedral sites in the  
30 lattice (approximately two Angstroms in palladium), and  
n is an odd integer. The addition of an AC ripple signal  
may be employed to tune the field for appropriate deuteron  
wavelength.

35 The barrier is placed perpendicular to the electric  
field, which is the preferred direction of migration of  
the deuterons. In some configurations, the barrier may  
interface with the crystal on more than one plane to block

1        deuterons driven by components of the electric field  
parallel to more than one of the  $\langle 1,1,0 \rangle$  directions of the  
lattice.

5                The electric field in the electrode itself is  
determined in part by the physical connection of the  
electrode to the electrical potential. The electrical  
field in the palladium cladding in the preferred  
embodiment is maintained substantially perpendicular to  
10        the surface of the cladding by the use of a metallic  
support having high conductivity and significant depth  
dimension with respect to the cladding. In addition, as  
the deuterium atoms diffuse into the palladium cladding,  
the resistance of the cladding increases. The net effects  
15        of the physical geometry of the support and the increased  
resistance of the palladium cladding is the displacement  
into the metallic support of the majority of current flow  
to the potential. Consequently, the electric field in the  
palladium cladding remains essentially perpendicular to  
the surface of the electrode and the cladding.

20                If enhancement of the direction of the electric field  
in the cladding is required, strips of insulator may be  
added to the surface of the palladium cladding, extending  
into the cladding perpendicular to the surface and to the  
direction of net current flow to the potential.  
25        Channeling of current perpendicular to the surface  
accomplished by the insulating strips enhances the field  
perpendicular to the surface.

30                An embodiment of this form is shown in FIG. 6 in  
which long single crystals 610 are laminated between  
insulating strips 612 onto a polycrystalline cladding 614.  
The single crystals have a  $\langle 1,1,0 \rangle$  axis parallel to the  
electric field which is forced to remain in a direction  
perpendicular to the electrode surface all the way through  
the single crystal.

35                These long single crystals may be grown using a  
floating zone electron beam method. Polycrystalline rods  
of 4 - 5 mm in diameter are bombarded with an electron

1 beam in a vacuum environment of  $10^{-5}$  to  $10^{-6}$  Torr. The  
beam melts a region of the rod approximately equal to the  
diameter in length. The heated section of the rod  
recrystallizes as a single crystal. The rod is then  
5 advanced and a new length bombarded by the beam similar  
to a zone refining process. Details of the process may  
be found in Pamplin, B.R., Crystal Growth, Pergamon Press  
(1975) PP 140 -142. Impurities are evaporated during this  
process, further enhancing the crystal.

10 The polycrystalline cladding in the embodiment shown  
in FIG. 6 is silver or other nonreactive metal having a  
higher thermal conductivity than palladium and a smaller  
crystalline structure to provide a deuteron diffusion  
barrier.

15 In each of the embodiments described, the structural  
member provides the electrical contact in addition to a  
barrier to diffusion and tunneling of the deuterons in the  
palladium cladding perpendicular to the surface of the  
electrode. As previously described, the electric field  
20 direction in the cladding layer is substantially  
perpendicular to the surface of the layer, resulting in  
the structural support being perpendicular to the field  
to provide an effective barrier for the deuterons.

Referring now to FIG. 3 the preferred configuration  
25 of the electrodes is suitable to provide a self-contained  
electrolytic cell. The corrugated shape of the cathode  
10 and complementary shape of the anode 16 when placed in  
spaced relation provide two sides of an enclosure for the  
heavy water electrolyte of the cell. Sealing at the  
30 peripheral extremities of the electrodes may be  
accomplished by a insulating quartz cap 310 employing  
quartz to metal seals 312 at the cathode and anode.  
Similar insulating quartz caps may be employed at the  
upper and lower boundaries of the electrodes with  
35 appropriate connections for introducing the electrolytes  
and withdrawing the evolved gases.

1           As shown schematically in FIG. 4 multiple cells 410  
may be placed in a common pressure vessel 412. The  
electrolyte is supplied to each of the cells through  
5           connection 414. Deuterium and oxygen gas evolved at the  
surfaces of the electrodes in each cell are scavenged  
through connections 416 and 418, respectively. As  
previously described with respect to FIG. 1, a spun quartz  
fiber screen or other appropriate device may be employed  
to prevent mixing of the deuterium and oxygen gases in the  
10          electrolytic cells.

Coolant is introduced to the pressure vessel at  
connection 420 and circulated through the channels formed  
by the electrodes external to the electrolytic cell.  
Withdrawal of the circulating coolant is accomplished at  
15          connection 422. In the embodiment shown high purity  
ordinary water ( $H_2O$ ) is used as the coolant. Appropriate  
corrosion protection steps for the structural members of  
the electrodes exposed to the coolant must be employed to  
prevent degradation of the electrodes.

20          The circulating coolant provides the heat exchange  
medium for withdrawing energy from the reactor which is  
created by fusion in the palladium reactor lattices of the  
cathodes in the electrolytic cells. An embodiment  
employing standard steam plant operating parameters  
25          provides an operating temperature of 650°C. This results  
a factor of approximately two for safety margin to the  
melting temperatures of materials employed in the  
electrolytic cells and reactor pressure vessels (steel  
1600°C, nickel 1455°C, palladium 1549°C, platinum 1773°C,  
30          copper 1100°C).

Operation at 650°C requires pressurization above  
2200psi to prevent boiling in the system. The coolant  
loop in the reactor and the heavy water electrolyte are  
therefore maintained above 2200psi.

35          FIG. 5 provides a schematic for an embodiment of a  
power generation system employing the reactor of FIG. 4  
and a dual coolant loop power generation system. A heavy

1 water electrolyte tank 510 stores the electrolyte which  
 is pumped to the electrolytic cells through a first feed  
 pump 512 to the pressure vessel. The evolved oxygen and  
 deuterium gas from the electrolytic cells are stored in  
 5 tanks 514 and 516, respectively. Liquefaction of the  
 gases may be employed to reduce storage volume. The  
 primary coolant loop provides cooling water through a  
 second pump 520 to the pressure vessel. Coolant exiting  
 the pressure vessel is routed through a heat exchanger 522  
 10 and returned to the pump 520. A secondary coolant loop  
 employing water or other appropriate coolant receives heat  
 in the heat exchanger to generate power in the turbine 524  
 after which it is condensed in condenser 526 and returned  
 to the heat exchanger by a third pump 528.

15 The present invention also controls the temperature  
 of the electrolytic solution. The temperature  
 relationship

$$T_n = (2n+1)^2 h^2 / 32mkL^2$$

20 provides a basis for hypothesizing the transmission  
 resonance level spectrum for a palladium deuteride (PdD)  
 lattice. From the experimental evidence of Pons and  
 Fleischmann previously described, transmission resonance  
 25 is present at room temperature (293K). By solving for the  
 well width for  $T_n = 293k$  we find

$$\begin{aligned} L_n &= (2n+1) (0.349\text{\AA}) (243K/293K)^{1/2} \\ &= (2n+1) (0.318\text{\AA}) \end{aligned}$$

30 Therefore, for integers 0,1,2,3,4, etc. the following well  
 widths are defined

$$0.318\text{\AA}, 0.953\text{\AA}, 1.59\text{\AA}, 2.22\text{\AA}, 2.86\text{\AA}, \text{ etc.}$$

35 The lattice parameter for Pd in the  $\alpha$  phase is well known  
 to be 3.89Å. It is also known that the lattice undergoes



1 a uniform 11% expansion to reach the  $\beta$  phase. Therefore,  
 the new lattice parameter is given by  $3.89\text{\AA} \times (1.11)^{1/3}$ .  
 The separation of two deuterons residing at neighboring  
 octahedral interstitial sites is the value of the lattice  
 5 parameter divided by  $(2)^{1/2}$  or  $2.85\text{\AA}$ .

Selecting the width of the a well formed by the  
 ascending Coulomb barriers of neighboring deuterons in the  
 lattice as  $2.86\text{\AA}$  a temperature level scheme for  
 transmission resonance levels may be obtained for a  
 10 deuterium loaded  $\beta$  phase palladium lattice with deuterons  
 as the diffusing particles (diffusons).

$$T_n = (2n+1)^2 (27\text{K}) (1.047\text{\AA}/2.86\text{\AA})^2 \\ = (2n+1)^2 (3.62\text{K})$$

15 FIG. 7 portrays this level scheme.

A temperature width,  $\Delta T_n$ , is present at each level.  
 $\Delta T_n$  is associated with the variation in the well width  
 due to thermal vibration. This may be characterized as  
 20 phonon exchange between the deuterons responsible for the  
 Coulomb barrier wells and the metal lattice. This  
 variation,  $\Delta L$ , in the well width due to vibration from  
 the level  $T_n$  may be estimated by

$$25 \quad (1/2)m \omega^2 (\Delta L)^2 = (1/2)kT$$

therefore,

$$\Delta L = (kT/m \omega^2)^{1/2}.$$

30

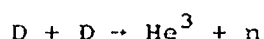
Then,

$$\Delta T_n = 2(\Delta L/L)T_n.$$

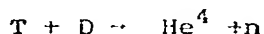
35 These level widths provide transmission bands for  
 propagation of the deuterons in the lattice. Transitions  
 via phonon exchange with the lattice would become

1 significant whenever the thermal energy  $kT$  associated with  
 an "average" phonon becomes of the order of  $kT_n$ , i.e. when  
 $T=T_n$ . Neutron emissions may be created by transitions of  
 diffusing deuterons between levels. The burst nature of  
 5 these emissions may associated with the boson nature of  
 neutrons since the symmetric wave function gives bosons  
 the tendency to be "gregarious".

The deuterium reactions in the lattice may be



The following nuclear reactions may also be catalyzed from  
 15 the system using the LiOD and heavy water electrolyte via  
 the transmission resonances within the lattice:



Reactions of  $Li^7$  to produce tritium may also be present.

25 The  $Li^6$  - on - a - deuteron reaction to produce  $He^4$   
 is hypothesized as the primary energy producing reaction  
 in the present invention. Again solving for the well  
 width in the lattice, now for  $Li^6$  diffusons in a PdD  
 lattice, we see

30 
$$L_n = (2n+1)(0.1838\text{\AA})$$

This generates widths of

35 
$$0.18\text{\AA}, 0.55\text{\AA}, 0.92\text{\AA}, 1.29\text{\AA}, 1.65\text{\AA},$$

$$2.02\text{\AA}, 2.39\text{\AA}, 2.76\text{\AA}, 3.12\text{\AA}, \text{ etc.}$$

1

Again employing the width closest to that of 2.85Å characteristic of the PdD lattice, 2.76Å, we obtain

5

$$T_n = (2n+1)^2 (1.303K)$$

resulting in levels of

10

1.3K, 11.7K, 32.6K, 63.8K, 105.5K, 157.7K,  
220.2K, 293.2K, 376.6K, etc.

For  $Li^7$  diffusons within the PdD lattice we find

15

$$L_n = (2n+1) (0.1702Å)$$

resulting in

$$L = 2.89Å$$

20

leading to a result for the transmissions levels temperatures of

$$T_n = (2n+1)^2 (1.0145K)$$

25

with transmission levels of

1.0K, 9.1K, 25.4K, 49.7K, 82.2K, 122.8K, 171.5K,  
228.3K, 293.2K, 366.2K, etc.

30

The presence of a transmission resonance level at 293.2K (20C) or room temperature in the deuteron,  $Li^6$ , and  $Li^7$  transmission level structures and numerous transition levels below room temperature supports the presence of heat producing reactions in a room temperature system.

35

Increasing the temperature of the electrolytic solution shifts the Boltzmann distribution for the diffusons to higher energies. This gives more overlap with the higher

1     order (greater  $n$ ) transmission levels, which also have  
more of a thermal width. This enhances the probability  
of transmission of the diffusons with a consequent  
enhancement for nuclear reactions.

5             The tunneling process ordinarily associated with a  
cold fusion reaction is sensitive to the mass of the  
tunneling particle. For example, R. Bush and R. Eagleton  
in "Cold Nuclear Fusion: A Hypothetical Model to Probe an  
Elusive Phenomenon", Journal of Fusion Energy, accepted  
10   for publication August 1989, show that the transmissivity  
for cold fusion not involving a metal lattice is given  
approximately by

$$T = \exp\{-\alpha(m/E)^{1/2}\}$$

15             where  $\alpha$  is a constant,  $m$  is the mass of the tunneling  
particle, and  $E$  is the energy of the particle incident  
upon the Coulomb barrier. For particles of equal energy  
 $E$ , the probability for tunneling decreases strongly as the  
20   mass  $m$  increases. In contrast, cold Fusion within a metal  
lattice such as the palladium deuteride in the present  
invention can actually increase as mass increases. This  
is clear from the equation for the de Broglie wavelength  
of the diffusing particle

25             
$$\lambda = h/(2mE)^{1/2}$$

              since for particles of equal energy,  $E$ ,  $\lambda$  is smallest for  
the particle of largest mass. The advantage of smaller  
30    $\lambda$  is that there are more ways in which the transmission  
resonance condition can be satisfied. The formula for  $T_n$   
specifying the resonant transmission levels also shows  
this, since mass  $m$  occurs in the denominator. Based on  
this, nuclear reactions in the PdD lattice involving  $\text{Li}^6$   
35   and  $\text{Li}^7$  may predominate over those involving deuterons.  
(Additionally,  $\text{Li}^6$  may predominate over  $\text{Li}^7$  since the  
former are bosons while the latter are fermions.)

1           Similar calculations may be made for alternate  
metallic lattices such as titanium which may be used for  
electrode materials. Titanium deuteride as a lattice does  
not provide the large number of transmission resonance  
5       levels present in palladium deuteride for the same  
temperature with deuterons as the diffusons. However,  
structural or other considerations may make the use of a  
titanium lattice in the cathode desirable with an  
alternate diffuson.

10           Enhancement of the transmission resonance levels  
available for the deuterons is accomplished in the present  
invention by heating the electrolyte entering the reactor  
in a feed water heater 530 as shown in FIG. 5. The heater  
is operated to achieve electrolyte temperatures of 500 to  
15       600 C to provide the greatest number of transmission  
resonance levels for the deuterium and  $\text{Li}^6$  in the  
electrolyte to be transmitted through the lattice.

Electrical resistance heating, fuel fired heat  
exchangers or other methods may be used for the feedwater  
20       heater. Recombination of the  $\text{O}_2$  and  $\text{D}_2$  gases produced by  
the cell may be used for the fuel heat source or as an  
energy supplement for the feedwater heater by returning  
the gases to the heater shown schematically by lines 532  
and 534 in FIG. 5.

25           The use of high purity  $\text{Li}^6$  for the LiOD in the  
electrolyte provides a "clean" reactor avoiding production  
of tritium from  $\text{Li}^7$ . An optimum electrolytic solution  
having .1 to .5 molar LiOD with a purity of 99.5% for  $\text{Li}^6$   
is used.

30           A power factor  $P(T)$  is used to compare the  
transmission aspects of the reactions in the present  
invention.  $P(T)$  is proportional to the total number of  
diffusing deuterons and therefore is equal to the number  
of deuterons in metastable states. The population of  
35       deuterons in the  $n$ th state is proportional to the  
Boltzmann factor therefore

$$\begin{aligned}
 P(T) &= \sum \exp(-E_n/kT) \\
 &= \sum \exp(-T_n/T).
 \end{aligned}$$

The value of  $P(T)$  increases with increasing temperature  $T$  due to the negative exponentials. A positive temperature coefficient for the cold fusion process is therefore present. A plot of the power factor for palladium deuteride is shown in FIG. 8.

Similarly, if it is assumed that all other aspects such as nuclear cross-sections remain the same at different temperatures the rate of change of the power factor with temperature follows directly

$$dP/dT = T^{-2} \left[ \sum T_n \exp(-T_n/T) \right].$$

A plot of  $dP/dT$  is shown in FIG. 9 for palladium deuteride.

The rate of change of the dimensionless power factor with temperature has an inverse square dependence upon the temperature. Similar calculations may be made for a Titanium deuteride lattice.

Near the surface of the electrode the diffusion of the deuterons (and other particles) in the lattice may be described in terms of the Maxwell velocity distribution for a temperature  $T$ .

$$dN(v)/dv = T^{-3/2} v^2 \exp(-mv^2/2kT)$$

where  $N$  is the number of diffusing particles with velocity  $v$ . A velocity  $v_n$  corresponding to a transmission resonance is given by

$$v_n = h/m \lambda$$

where the de Broglie wavelength  $\lambda$  satisfies the resonance condition. The number of diffusing deuterons having this velocity corresponding to a particular value of  $n$  is

1 proportional to the area under the curve of  $dN(v)/dv$   
 versus  $v$  for the value  $v=v_n$ . This, of course, is zero.  
 Therefore, it is the phonon exchange between the lattice  
 and the deuterons whose Coulomb barriers form the wells,  
 5 that results in a thermal width for the resonance  
 transmission levels, thus providing candidate deuterons  
 for transmission. The velocity width  $\Delta v_n$  corresponding  
 to the  $\Delta L$  is given by

10 
$$\Delta v_n = 2 \Delta L m v_n^2 / h.$$

The relation of  $v_n$  to the  $n$ th order transmission resonance  
 level is

15 
$$m v_n^2 / 2 = k T_n.$$

Taking the thermal width into account for the transmission  
 resonance velocity, the number of candidate deuterons for  
 resonant transmission is now proportional to the area  
 20 under the curve of  $dN(v)/dv$  versus  $v$  between  $v_n - (\Delta v_n)/2$   
 and  $v_n + (\Delta v_n)/2$ . This can be approximated by

$$\begin{aligned} ([dN(v)/dv]_{v_n} \Delta v_n) &\propto T^{-1} T_n^{3/2} \exp(-T_n/T) \\ &\propto T^{-3/2} T_n^{1/2} \Delta T_n \exp(-T_n/T) \end{aligned}$$

25 Since  $([dN(v)/dv]_{v_n} \Delta v_n)$  has a maximum when  $T = T_n$   
 setting the derivative with respect to the temperature  $T_n$   
 equal to zero will provide a maximum:

30 
$$d/dT [T^{-1} T_n^{3/2} \exp(-T_n/T)] = 0$$

Solving this equation shows the maximum at

$$T_{\max} = T_n.$$

35 This also corresponds to the most probable velocity for  
 the Maxwell velocity distribution. This implies that

1 neutron bursts may be produced by deuterons with  
correlated velocities with the maximum of the velocity  
distribution corresponding to a transmission level,  $v_n$ .

This allows a power factor of

5

$$P(T) = T^{-1} \Sigma T_n^{3/2} \exp(-T_n/T)$$

for comparing powers at different temperatures for a  
particular lattice (e.g. PdD). Thus, for  $Li^6$  lithons as  
10 diffusons in a PdD lattice it can be shown that the power  
yield would be three times as great at 600 K as at 293 K.  
Nuclear factors should enhance this.

As a second embodiment, the growth of dendrites or  
sintering of palladium grain crystals on the surface of  
15 the cathode is provided to enhance a surface reaction. In  
this embodiment, the structural support of the electrode  
is first clad with a thin film of polycrystalline  
palladium foil, or other conductive nonreactive material,  
by electroplating, vapor-deposition or other technique,  
20 and a layer of single crystal palladium grains is sintered  
to the surface of the palladium cladding. Annealing of  
the sintered grains is accomplished to create essentially  
a single crystal in each grain.

A temperature coefficient based on this power factor  
25 is also positive., and assuming other conditions to be the  
same, more power is yielded at higher temperatures. The  
Maxwell velocity distribution is shifted by increasing  
temperature for higher values of  $v$  thereby allowing more  
transmission levels,  $v_n$ , to make a significant  
30 contribution. The thermal width,  $\Delta T_n$ , of a transmission  
level is proportional to both  $n$  and  $T^{1/2}$ .

The present invention provides opportunity for cold  
fusion by loading a metal deuteride lattice and providing  
diffusing particles, deuterons and lithons, with energies  
35 overlapping the transmission resonance levels defined by  
 $T_n$ . Loading of the lattice is enhanced by arrangement of  
the crystal lattice parallel to the electric field between



1 the electrodes and providing a barrier to prevent  
diffusion completely through the lattice as previously  
described. Loading of the lattice is accomplished with  
a current density of about  $10 - 50 \text{ mA/cm}^2$  to create a  $\beta$   
5 phase by loading deuterons in the interstitial sites in  
the lattice. Achieving stoichiometry of at least .7 in  
the reactive portion of the lattice is desirable in the  
loading.

Loading is conducted with the lattice and electrolyte  
10 at room temperature or lower. After loading is complete,  
the probability of fusion reaction is enhanced by  
increasing the electrolyte temperature using the feed  
water heater. "Bumping" of the current between the  
electrodes may be employed to assist in starting the  
15 resonant transmission of particles into the loaded  
lattice. The AC ripple previously described will be  
sufficient in most applications.

As previously described control of the fusion  
reaction in the individual cells is accomplished by  
20 varying the current density in the electrodes thereby  
controlling migration of deuterons and lithons through the  
lattice to the barrier points. Variation in the  
electrolyte temperature by increasing or decreasing heat  
input through the feed water heater is also employed to  
25 control the reaction.

Operation of the reactor will eventually "poison" the  
electrodes with  $\text{He}^4$  in the lattice. Further, the lattice  
sites in which fusion has taken place and those  
surrounding will be damaged due to the production of heat.  
30 The electrodes in the reactor must then be refurbished or  
replaced.

In operation, application of electric potential to  
the reactor cells could be alternated for periodic  
intervals to allow annealing of the crystalline lattice  
35 or reformation of the crystal in the sites damaged by  
fusion by heating from adjacent cells to effectuate "self  
repair". If electrode annealing is too slow at  $650^\circ \text{C}$

1 design of the operating temperature and pressure of the  
reactor may be correspondingly increased as required  
within limits imposed by the structural materials.

5 Reduction of pressure of the electrolyte in  
combination with heating will provide some limited removal  
of the  $\text{He}^4$  in the lattice. It should be noted that  
removal of the reactor electrodes and recovery of the  $\text{He}^4$   
present will provide significant cost benefit.

10 As alternative embodiments to that described  
previously, the reactor lattice may be arranged on a  
symmetrical electrode such as a sphere or cube where all  
surfaces of the electrode exposed to the electrolyte are  
perpendicular to the electric field and the field inside  
15 the electrode is aligned essentially through the geometric  
centroid of the electrode. Those skilled in the art will  
recognize fabrication and electrical connection techniques  
such as an insulated probe electrically connected at the  
tip with the geometric centroid of the electrode to  
20 provide the potential to the electrode. This arrangement  
of all electric field lines radiating from the center of  
the electrode provides a self-induced "boundary" at the  
center of the electrode preventing the deuterons from  
exiting the electrode. Practical heat removal in this  
configuration may prove difficult.

25 It should further be noted that the reactor design  
of the present invention is compatible with the structural  
components of existing fission reactor designs. The  
fission cores in these reactors could be replaced with the  
cold fusion electrode systems of the present invention as  
30 a retro-fit significantly reducing capital cost for  
building such fusion reactors and providing a beneficial  
use for decommissioned fission reactors in providing clean  
power generation.

35 Having now described the invention in detail as  
required by the patent statutes, those skilled in the art  
will recognize potential modifications to the geometry and  
materials employed in the electrodes including the

1       crystalline lattices and possible power generating plant  
configurations without departing from the scope and intent  
of the invention as described in the following claims.

5

10

15

20

25

30

35

---

## 1 WHAT IS CLAIMED IS:

1. An apparatus for producing heat energy through cold fusion comprising:

5 a crystalline reactor lattice having octahedral interstitial sites defined by atoms of the lattice, and the atoms having parallel bonds on opposite sides of the octahedral sites;

10 a means for maintaining an electrolytic solution including heavy water and metal deuterioxide as a source of deuterons and metal ions for diffusing particles in communication with a surface of the crystalline reactor;

15 means for generating an electric field perpendicular to any pair of parallel bonds of a significant plurality of the interstitial sites, the electric field having a magnitude causing the average wavelength of the diffusing particles, between collisions, to be equal to a transmission resonance wavelength;

20 means for creating a boundary which blocks the lattice perpendicular to the electric field in the lattice at a location of lower electric potential than the surface of the crystalline reactor; and,

means for heating the electrolytic solution.

25 2. An apparatus as defined in claim 1 wherein the crystalline reactor lattice comprises a plurality of single metallic crystals of face centered cubic structure oriented in any  $\langle 1,1,0 \rangle$  direction with respect to a surface of the crystal.

30 3. An apparatus as defined in claim 2 wherein the metallic crystal is palladium.

35 4. An apparatus as defined in claim 3 wherein the metal deuterioxide is lithium deuterioxide and the metal ions are lithons.

1           5. An apparatus as defined in claim 3 further comprising a structural member having a polycrystalline cladding to which the reactor lattice is bonded.

5           6. An apparatus as defined in claim 5 wherein the lattice comprises single crystal grains of palladium sintered to the polycrystalline cladding.

10           7. An apparatus as defined in claim 4 wherein the means for generating an electric field comprises:

          a cathode, the reactor lattice being an integral portion of the cathode;

          an anode immersed in the electrolytic solution, and,

15           an electric potential connected between the anode and cathode.

20           8. An apparatus as defined in claim 7 wherein the electric potential is adjustable.

25           9. An apparatus for producing heat energy from cold fusion of diffusing particles comprising:

          an electric potential;

          a heavy water and lithium deuterioxide electrolyte bath;

          a first electrode connected to the potential and having at least one surface immersed in the bath;

30           a second electrode connected to the potential having at least one surface, substantially parallel to the surface of the first electrode at all points of tangency, said one surface immersed in the bath thereby completing the circuit and creating an electric field in the bath and the second electrode further having:

35           a metallic face centered cubic crystalline reactor lattice exposed at the surface of the second electrode, with a substantial plurality of octahedral

1 interstices of the lattice oriented with the  $\langle 1,1,0 \rangle$   
direction perpendicular to the surface,

5 a metallic boundary, perpendicular to the  
electric field in the second electrode, at which the  
lattice terminates thereby preventing further tunneling  
and diffusion by diffusing particles in a direction  
parallel to the electric field, and,

a means for controlling the temperature of the  
electrolyte.

10

10. An apparatus as defined in claim 9 wherein the  
lattice terminates at a metallic boundary on each surface  
not in contact with the electrolyte thereby preventing  
tunneling and diffusion by the deuterons from the lattice.

15

11. An apparatus as defined in claim 9 wherein the  
electric potential is controllable and reversible.

12. An apparatus as defined in claim 10 wherein the  
20 crystalline reactor lattice comprises a plurality of  
single crystals and the metallic boundary comprises a  
structural member connected to the electric potential and  
further comprising dielectric strips bonded intermediate  
the single crystals to form a laminated lattice, the  
25 dielectric strips perpendicular to a direction of primary  
current flow in the structural member.

13. An apparatus as defined in claim 9 wherein the  
electrolyte contains lithium deuterioxide having a 99.5%  
30 purity of  $\text{Li}^6$ .

14. An apparatus as defined in claim 13 wherein the  
molality of the lithium deuterioxide in the electrolyte is  
35 .1 to .5.

1           15. A method of producing power by fusion of  
diffusing particles with trapped particles in a lattice  
comprising the steps of

          fabricating a reactor cell by the steps of  
5           forming a plurality of single crystal palladium  
rods having a  $\langle 1,1,0 \rangle$  direction perpendicular to the  
surface of the rods,

          mounting the rods to a metallic structural  
member to form a first electrode,

10          placing a second electrode in parallel spaced  
relation to the first electrode,

          sealing between the adjacent peripheral edges  
of the first and second electrodes, and,

          introducing a heavy water and metal deuterioxide  
15       electrolyte between the electrodes as a source of  
deuterons and metal ions as diffusing particles,

          circulating a coolant around the reactor cell,

          applying an electric potential between the first and  
second electrode,

20       controlling the polarity and magnitude of the  
electric potential,

          heating the electrolyte, and,

          withdrawing heat energy from the coolant to generate  
power.

25           16. A method as defined in claim 15 wherein the  
metal deuterioxide used is lithium deuterioxide and the  
metal ions are lithons.

30           17. A method as defined in claim 15 wherein the  
heavy water in the electrolytic solution is 99.5% pure.

1           18. A method as defined in claim 15 further  
comprising the steps of:

installing a plurality of reactor cells in a pressure  
vessel, and,

5           alternately applying the electric potential to  
selected reactor cells to allow annealing of adjacent  
reactor cells.

10           19. A method as defined in claim 16 further  
comprising the step of reducing the pressure of the  
electrolyte during annealing of reactor cells to extract  
 $\text{He}^4$  contaminant from the electrodes.

15           20. A method as defined in claim 15 further  
comprising the step of loading the palladium lattice with  
deuterons to a stoichiometry of between .7 and 1 prior to  
heating the electrolyte.

20           21. A method as defined in claim 20 further  
comprising the step of providing an AC ripple on the  
electrode potential to bump the current in initiating a  
resonant transmission of lithons and deuterons into the  
lattice.

25           22. A method for creating a cold fusion reaction in  
a palladium lattice electrode comprising:

formulating a heavy water electrolytic solution  
with a molality of .1 to .5 lithium deuterioxide having a  
99.5% purity of  $\text{Li}^6$  to provide deuterons and lithons as  
30 diffusing particles;

immersing the palladium lattice in the  
electrolytic solution;

introducing an electric field of 10 to 50  $\text{mA}/\text{cm}^2$   
perpendicular to a  $\langle 1,1,0 \rangle$  direction in the crystals of  
35 the lattice to load the lattice;



1 loading the lattice to a stoichiometry of .7 to  
1 with deuterons from the electrolytic solution creating  
a  $\beta$  phase in the resulting palladium deuteride lattice;  
heating the electrolytic solution to a  
5 temperature exceeding a plurality of transmission  
resonance temperatures for the diffusing particles; and,  
controlling current in the electrode and  
temperature of the electrolytic solution to control the  
fusion reaction.

10

15

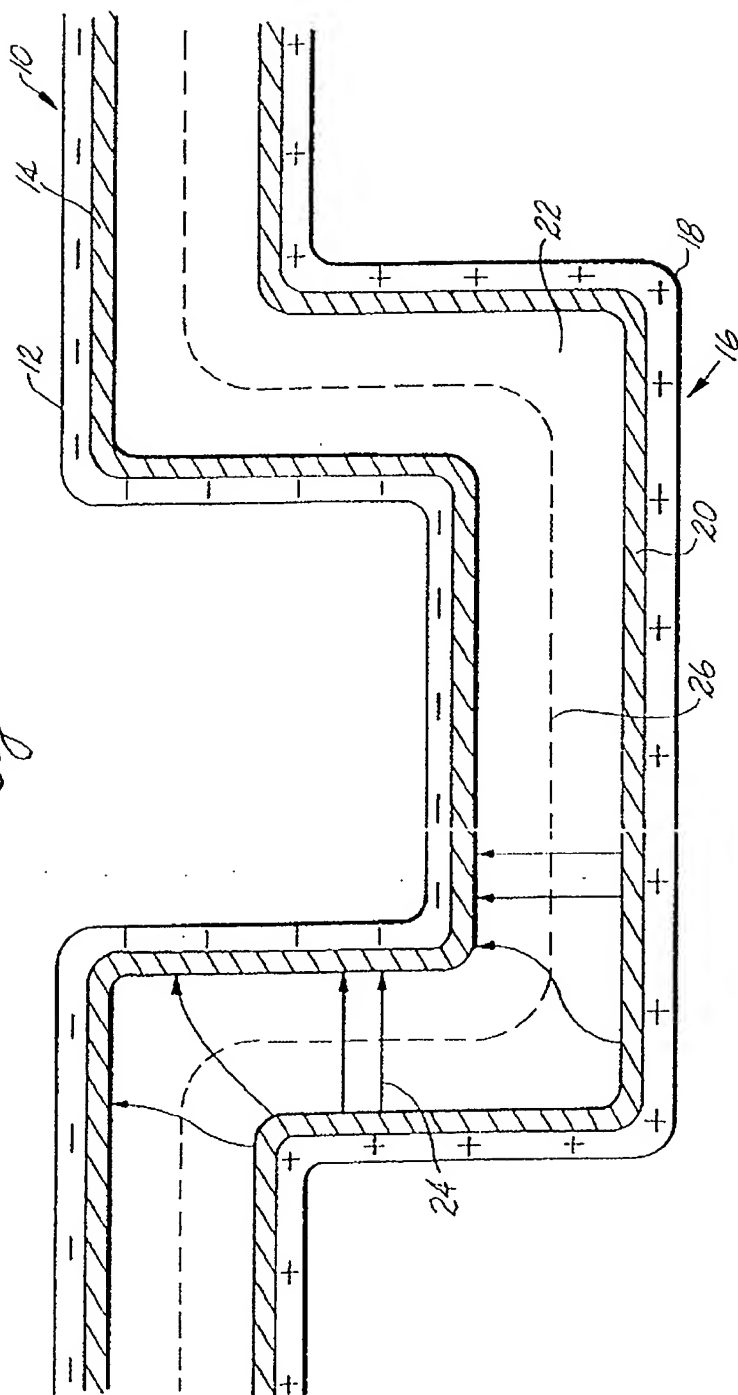
20

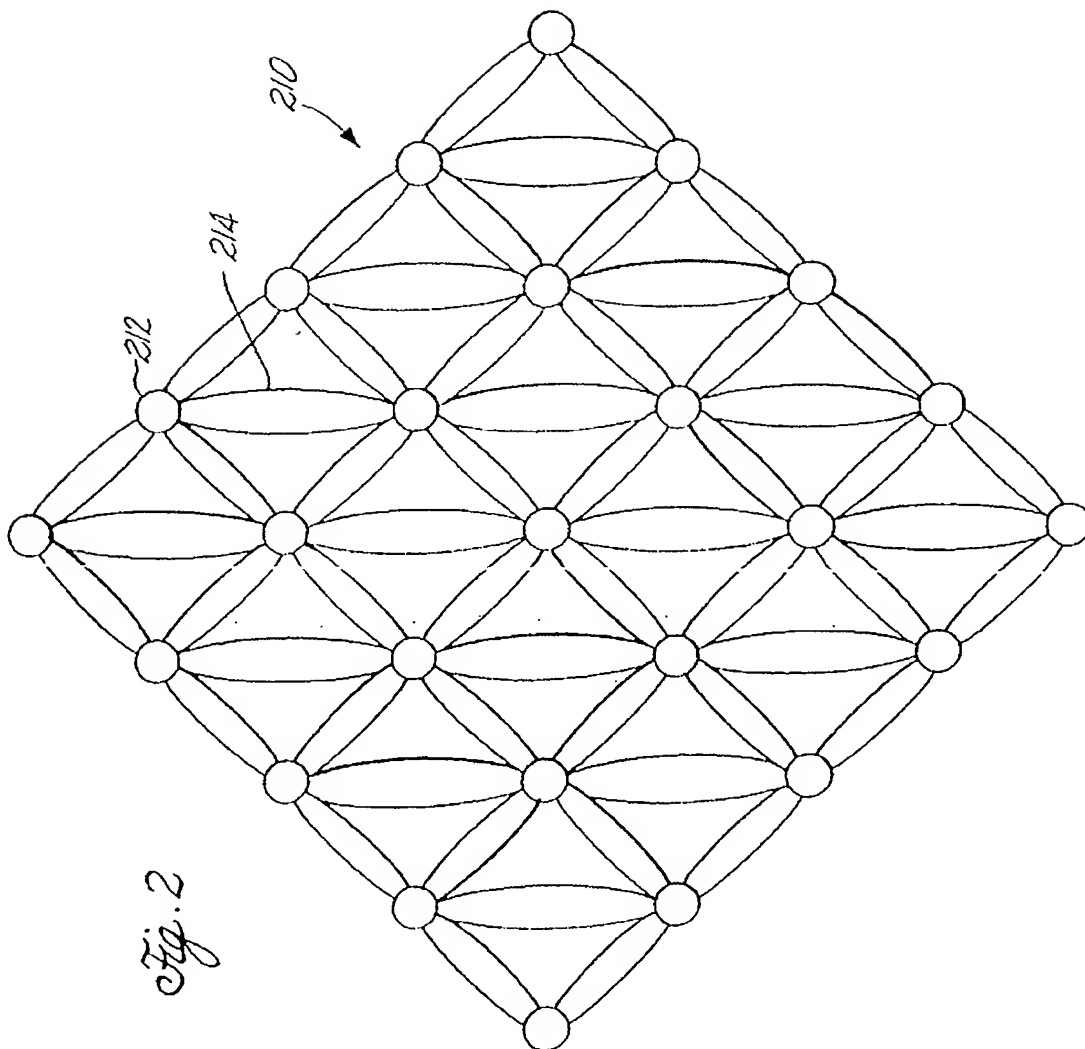
25

30

35

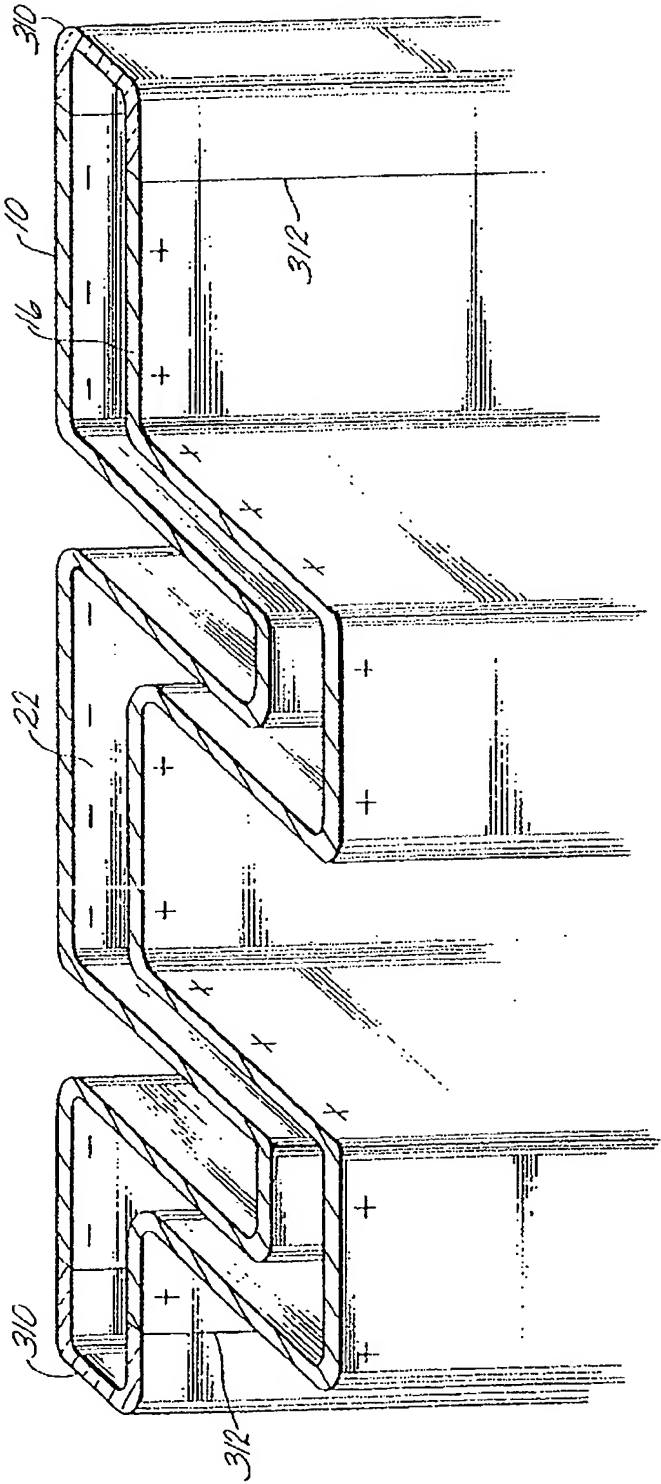
Fig. 1

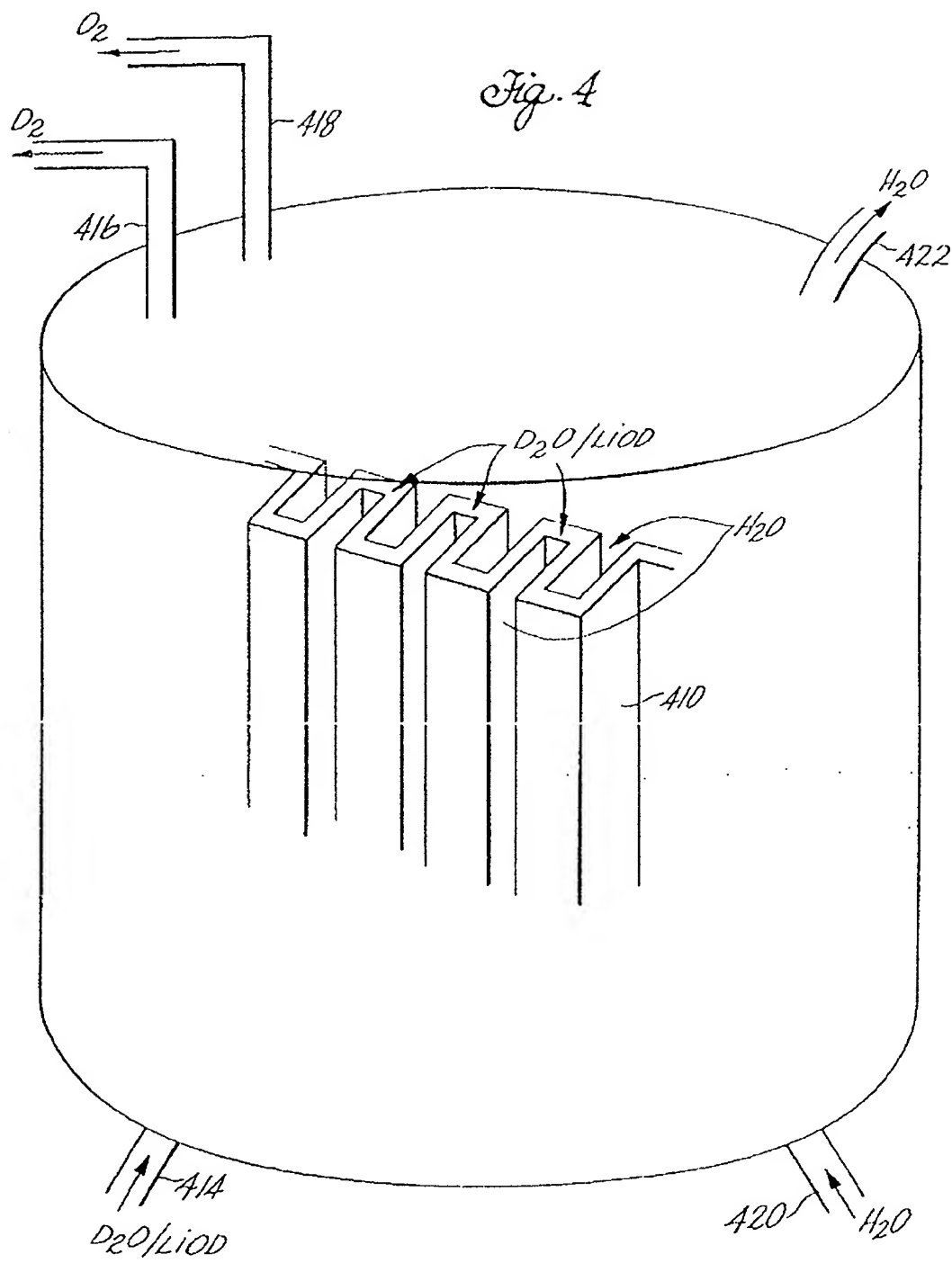




3/8

Fig. 3





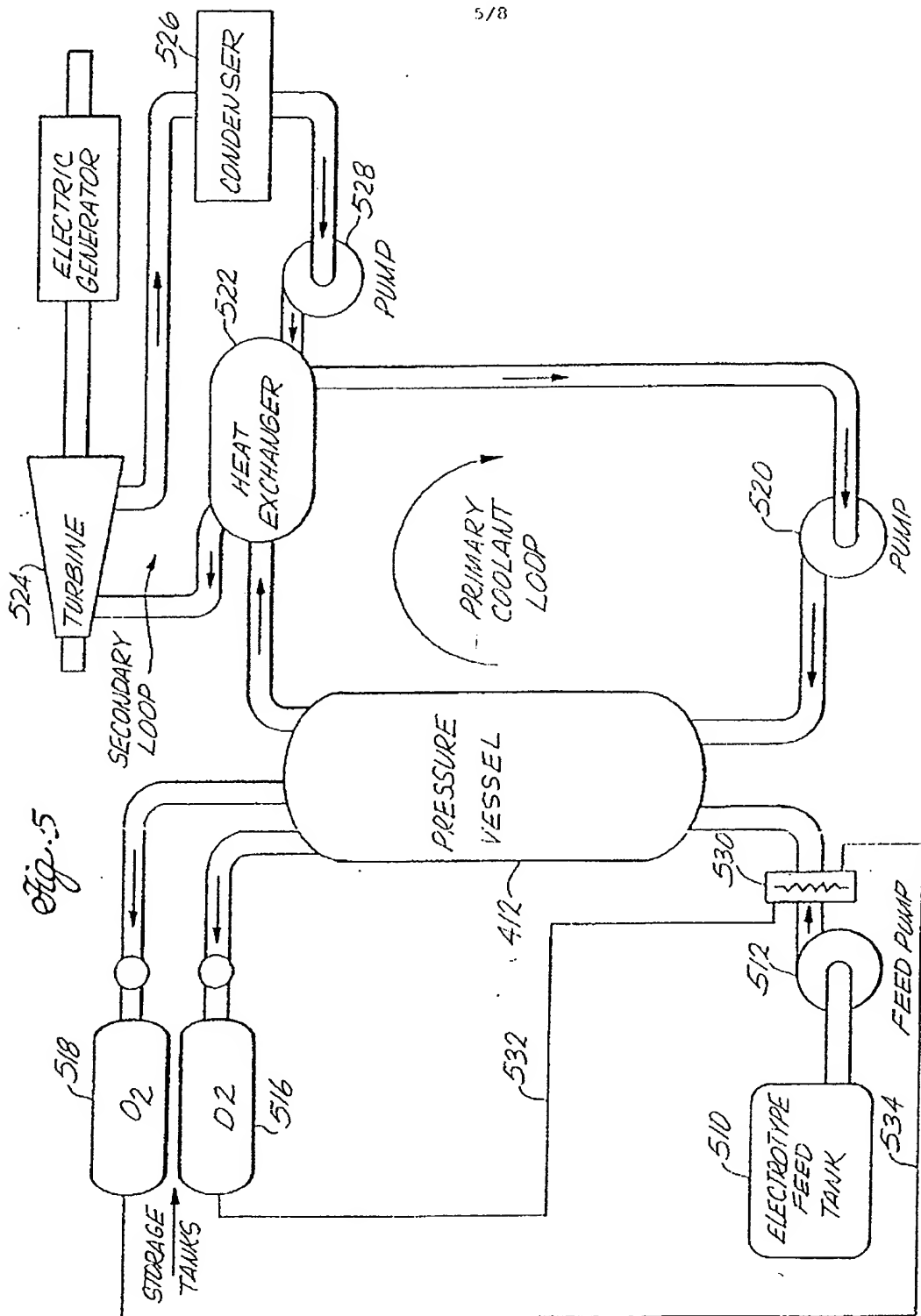


Fig. 6

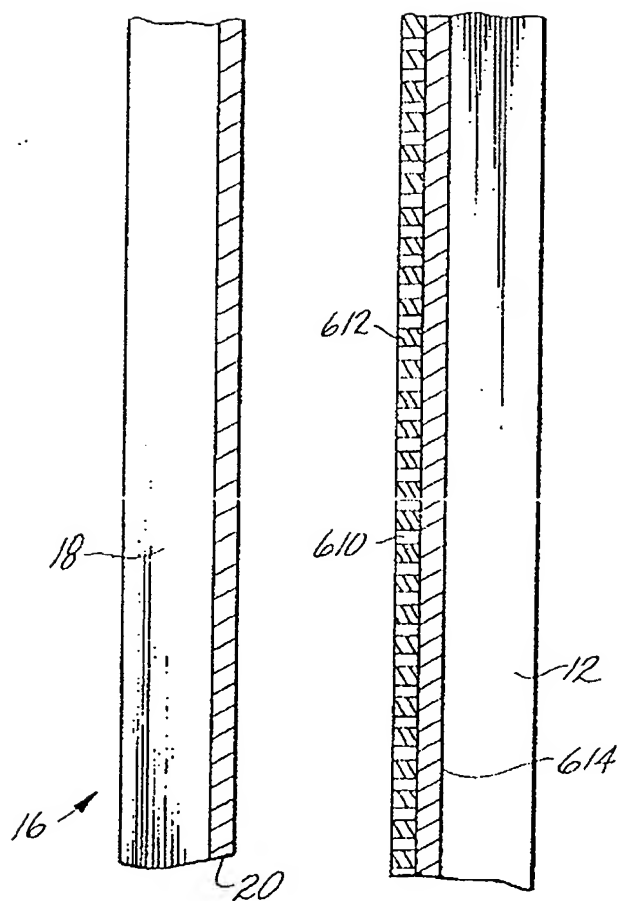
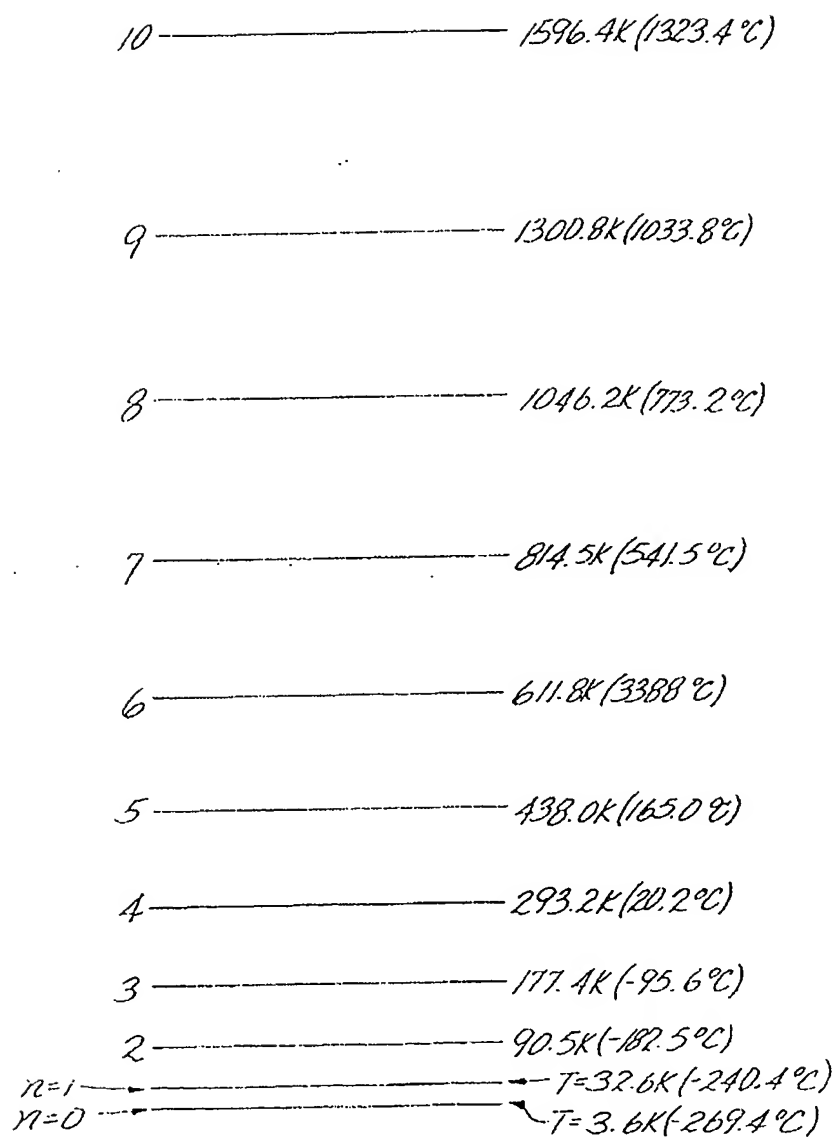
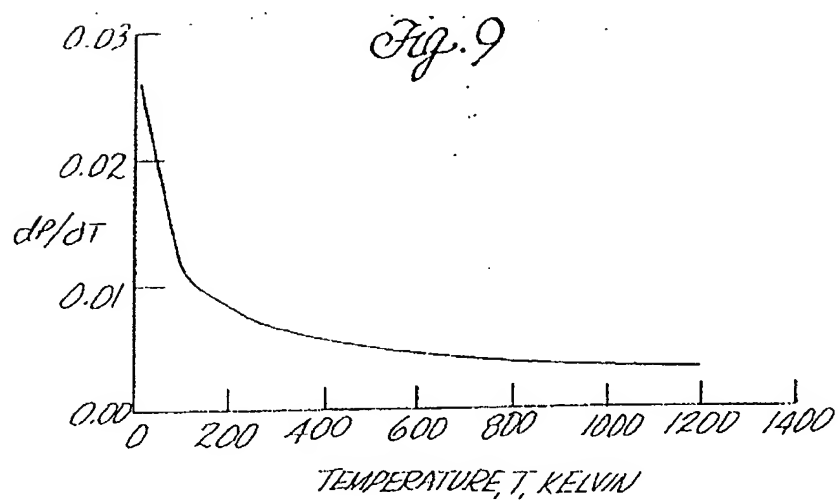
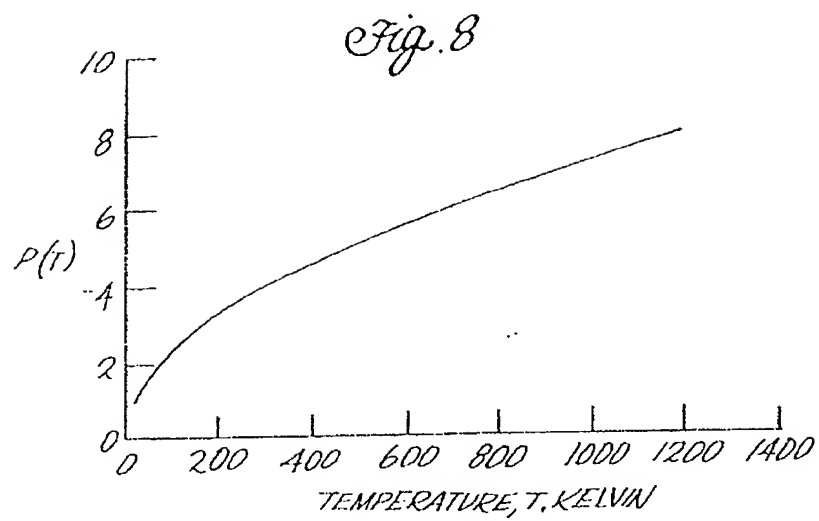


Fig. 7







# INTERNATIONAL SEARCH REPORT

International Application No. PCT/US90/07073

I. CLASSIFICATION OF SUBJECT MATTER (If several classification symbols apply, indicate all)		
According to International Patent Classification (IPC) or to both National Classification and IPC		
IPC (5): G21B 1/00		
U.S. CL.: 376/100		
II. FIELDS SEARCHED		
Minimum Documentation Searched *		
Classification System	Classification Symbols	
U.S.	376/100, 146, 114, 115 423/248, 645, 647.7 420/900, 463, 464, 465 204/129, 280R, 290F, 291, 292, 293, DIG. 8	
Documentation Searched other than Minimum Documentation to the extent that such Documents are included in the Fields Searched *		
III. DOCUMENTS CONSIDERED TO BE RELEVANT **		
Category *	Citation of Document, with indication, where appropriate, of the relevant passages **	Relevant to Claim No. 19
Y	Electroanalytical Chemistry, Volume 261, No. 2A, page 301-308, Parsons et al., April 1989.	1-22
Y	"The Palladium Hydrogen System", Academic Press 1967, page 1-180, Lewis; Figure 3.3.	2,3,6,12,15
Y	"The Kinetics of Hydrogen Absorption-Desorption by Metal", Pergamon Press 1981, page 329-343, Pick; page 341, Paragraph 2.	2,9,15,22
Y	US, A, 4,663,006 (YAO ET AL) 05 May 1987, Column 10, line 5 54-57; abstract.	18
Y	US, A, 4,373,176 (FINKELSTEIN ET AL) 08 February 1983; Column 1, lines 44-51.	21
Y	US, A, 3,455,845 (WICKE ET AL) 15 July 1969; Column 1, lines 47-52; column 2, lines 41-42.	5,6,10
Y	"Determination of the Hydrogen Content of Palladium and Palladium Alloys from Measurements of Electrode Potential and Electrical Resistance", Pergamon Press 1963, Volume 10, page 237-246, Barton et al; page 239, Paragraph 5.	10.
<p>* Special categories of cited documents: **</p> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"C" earlier document but published on or after the international filing date</p> <p>"L" document which may throw doubt on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"D" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> <p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to underscore the principles or theory underlying the invention</p> <p>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step</p> <p>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.</p> <p>"A" document member of the same patent family</p>		
IV. CERTIFICATION		
Date of the Actual Completion of the International Search *	Date of Making of this International Search Report *	
03 APRIL 1991	29 APR 1991	
International Searching Authority:	Signature of Authorized Officer	
ISA/US	DANIEL WASIL	

## FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

V. ☐ OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE<sup>1</sup>

This International search report has not been established in respect of certain claims under Article 17(2) (a) for the following reasons:

1. ☐ Claim numbers ... because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claim numbers ... because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claim numbers ... because they are dependent claims not drafted in accordance with the second and third sentences of PCT Rule 6.4(a).

VI. ☒ OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING<sup>2</sup>

This International Searching Authority found multiple inventions in this international application as follows:

See attachment

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.

2. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:

3. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:

4. ☐ As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

## Remark on Protest

- ☐ The additional search fees were accompanied by applicant's protest.  
☒ No protest accompanied the payment of additional search fees.

PCT/US90/07073

Continuation of PCT/ISA/210 item VI  
"Observations where unity of invention is lacking"

- I. Apparatus for producing heat energy; (claims 1-14).
- II. Method of producing power; (claims 15-21).
- III. Method of creating a cold fusion reaction; (claim 22).

The claims of these groups are directed to different inventions which are not so linked as to form a single general inventive concept. The inventions are not linked in operation and perform completely different operations. Note PCT Rule 13 and 37 CFR 1.475.

Within group I there is lack of unity under PCT Rule 13 between the following independent and distinct species :

- Ia. The embodiment having a polycrystalline cladding; (claims 1-11, 13, 14).
- Ib. The embodiment having dielectric strips bonded intermediate single crystals; (claims 1-4, 7-14).

## III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)

Category *	Citation of Document, <sup>14</sup> with indication, where appropriate, of the relevant passages <sup>15</sup>	Relevant to Claim No <sup>16</sup>
L	Nature, volume 344, page 401-405, 29 March 1990, Salamon et al., cited as casting doubt on inducing nuclear fusion in a catalyst by forcing hydrogen isotopes therein.	1-22
L	ORNL/FTR-3341, page 1-17, 31 July 1989, Cooke; Cited as casting doubt on inducing nuclear fusion in a catalyst by forcing hydrogen isotopes therein, see page 3-5.	1-22